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UNIVERSITY OF ALBERTA

EFFECTS OF MOTIVATIONAL FACTORS ON

A CHILD'S DISCRIMINATION OF

NUMBER

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF PSYCHOLOGY

OCTOBER 1966

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Effects of Motivational Factors on a Child's Discrimination of Number", submitted by Eugene Carl Lechelt in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

The purpose of this study was to examine the combined effects of different levels of economic status, class membership, and "need" on a child's discrimination of number.

Two major groups of children were employed: one group, called "low economic", was defined by the following three criteria, (a) residence in a low income area of the city, (b) identification as being members of the class of the poor, (c) familiarity with the purchasing power of money ("value") but without money ("means") being readily available; the other group, called "high-economic" was defined by (a) residence in an "upper-middle" income area of the city, (b) identification as being members of the "well-to-do" class, (c) familiarity with the purchasing power of money and having money readily available. Half of the children in each of these two groups were briefly shown displays of economically valueless slugs ("non-value" continuum) ranging in number from three (3) to twelve (12) and half were briefly shown dime displays varying in like fashion. "Value" was thus varied along a number dimension. A constant time (exposure) condition falling within the limits of the Bunsen-Roscoe law was used so as to have stimulation (number of targets) both within and beyond $\underline{S}$ "span of discrimination".

It was suggested that (1) there would be no significant difference in numerosity responses (estimates of the "manyness" of objects) between the groups when the number

of objects in either the "value" or "non-value" continuum was within their "span of discrimination" (range of accurate discrimination under brief exposure) i.e. less than six (6), (2) children of "low economic" group would have higher numerosity responses than children of "high economic" group when object displays both possessed "value" and were greater in number than the children's "span of discrimination" i.e. more than five (5), (3) there would be increased divergence between the numerosity responses of the two groups when the objects displayed possessed "value" and increased in number beyond the "span of discrimination" i.e. more than five (5).

The results provided satisfactory support for all three predictions and suggest that behavioral determinants (i.e. some motivational factors) may, under limiting conditions, functionally modify a child's discrimination of greater number (number which exceeds the child's "span of discrimination"). The results are given theoretical and systematic interpretation.

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Acknowledgments

I am particularly grateful to Dr. T.M. Nelson, supervisor of this thesis, for his valuable guidance in its preparation and for making it a challenging and rewarding experience. Thanks are also due to Dr. K. Wilson and Dr. P. Swartz for their helpful criticisms, suggestions, and cooperation.

Furthermore, the cooperation of Mr. T.D. Baker, Associate Superintendent of Schools, Mr. A.G. Baily, Assistant Superintendent of Elementary Schools, Mr. M. Kukl, Principal of Alex Taylor Elementary School and Mr. L. Lynn, Principal of Lendrum Elementary School, was invaluable in the collection of the data.

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Introduction

Three great ideas play a dominant role in explaining visual phenomena. The question "why do we see things as we do?" is answered by sensory, empirical, and motivational theories.

The law of Abney governing color mixture, Talbot's law governing brightness for intermittent stimulation, and the Bunsen-Roscoe law predicting effects from brief photic exposures are classic examples of sensory formulations. The phenomena referred to by these laws are considered sensory phenomena explicable by nativistic activity occurring within the visual tissue system.

The Bunsen-Roscoe law is of most immediate interest since it has been related to "span of discrimination", "span of attention", "span of cognition" or "span of apprehension".[1] This law states that for exposure times shorter than the critical duration (10 milliseconds for a point source and 50 for an extended source) the effective stimulus factor is neither Intensity (I) or Time (T) alone, but the quantity of energy represented by their product (I x T = C). It should be kept in mind however that the critical duration may also be dependent upon such stimulus conditions as wavelength and test area. The essential feature of this law is that as exposure time increases beyond the critical duration, it has no effect in determining a response to light onset since it does not change the stimulus for a given event.

Thus in terms of sensation, a bright short exposure is the same as a longer and correspondingly less intense exposure. For exposure times greater than this critical duration I x T does not form a reciprocal relationship equalling some constant (C) but rather I equals this constant (I = C).

One of the most sophisticated and relevant experiments concerned with delineation of processes governing numerosity response (numerosity is the name given by Stevens (1951) to a response to the "manyness" property of a collection of items which one can discriminate without counting) is that of Hunter & Sigler (1940). They sought to determine the number of dots S could perceive under varying values of exposure time and luminous intensity. Their results essentially confirm previous data arising from investigations of "span of apprehension" by Hamilton (1859), Jevons (1871), and Fernberger (1921); of "span of attention" as formulated by Oberly (1924); and of "range of attention" by Glannvile and Dallenbach (1929). In addition to determining the general number of items that can be accurately discriminated during a "single moment of consciousness", Hunter & Sigler generated precise description of Intensity (I) times Time (T) relationships and relate their data to Bunsen-Roscoe law. They interpret their results to mean that where the span is a single discriminatory event (1 - 8 dots) the Bunsen-Roscoe law holds up to that duration at which the sensory pathway elaboration is complete. Casperson & Schlosberg (1950), and Miller (1956), later essentially confirmed Hunter and

Sigler's results in finding 7 to 8 objects the limit of Ss accurate discrimination under limiting time conditions.

Empirical explanations of visual phenomena include such things as primary and secondary cues of depth, the "constancies", and motion parallax. Empirical formulations presume that many classes of visual phenomena are not to be explained by events occurring within a single pathway, but reflect the integrative action of a total central system functionally modified by previous stimulation. Variables affecting the learned ability to count, use number concepts, and form quantitative relations have been extensively invest- igated, but since these investigations are not of critical importance to this paper no atempt will be made to review them here.[2] In as much as perception has been identified with past experience however this matter will be touched upon again in the final discussion of perception.

Those involved in advancing the newest theoretical developments are known as Motivational, Functional, or Directive State theorists. Gardner Murphy (1947, pp. 30-31), a leading representative of this school, says "it is not that one system influences the other; it is that an isomorphic relationship obtains between the two broad classes of phen- omena - perceptual and motivational". And regarding the often imposed dichotomous relationship between sensory and functional determinants, Krech & Crutchfield (1948, p. 83) say "neither set operates alone; every perception involves both kinds of factors". The recent physiological invest-

gations of activational mechanisms have to an extent provided a biological rationale for this view although relatively few of the visual studies have actually involved direct (neurophysiological) considerations of innervation.

The effect of motivational factors upon the structuring and emergence of a visual event is called autism. The most often quoted definition of autism is that of Chein's to the effect that "it is the movement of cognitive processes in the direction of need satisfaction" (Levine, Chein, & Murphy, 1942, p. 283).[3] Also, Piaget in The child's conception of physical causality (p. 302) says "autism...
(is) thought in which truth is confused with desire".
Autism is hypothesized to result when "sets" provided by needs or affective components dominate and distort the cognitive reality to an extent that leaves $\underline{O}$ unaware of the distortion. Autism is considered more common among children and Piaget puts forth the idea that earlier autistic percepts lay a foundation for later veridical responses.[4] Recent years have seen many attempts to study and describe the operation of personality and social variables in the visual process to effectively demonstrate the existence of autism. The majority of these studies have been concerned with the role of "value" in vision (Ansbacher, 1937; Bevan & Dukes, 1951; Bruner & Goodman, 1947; Carter & Schooler, 1949; Dukes, 1955; Dukes & Bevan, 1952a; Gilchrist & Nesberg, 1952; Haigh & Fiske, 1952; Klein, Schlesinger & Meister, 1951; Luft, 1957; McCurdy, 1956; Pepitone, 1950;

Postman, Bruner, & McGinnies, 1948; Rock & Fleck, 1950; Sherif, 1935; Tajfel, 1957, 1959a, 1959b, 1963; Vernon, 1955).

Bruner & Goodman (1947) have perhaps given the greatest impetus to "value" research by demonstrating the interaction of "value" and size estimation. They report data showing that low economic status children overestimate the size of coins significantly more markedly than high economic status children, and that both groups tend to slightly underestimate the size of discs possessing no "value". The general hypothesis which they conclude their results confirm, is that the "greater the social value of an object the more it will be susceptible to organization by behavioral determinants" (p. 36).

The Bruner & Goodman study has been much criticized on methodological grounds and has been repeated several times in like manner, but with varying and sometimes conflicting results. Carter & Schooler (1949) failed to obtain significant differences of size estimation between high and low economic status children when the estimates were made with the coins present. Only when coin size was estimated from memory did they obtain significant results.

The difference between these two studies suggests that memory size is distinct from comparison size and that "need" or "value" factors may not modify all perceptual processes. Bruner & Rodrigues (1953) attempted to resolve the major procedural differences between the studies. They conclude that while "value" by itself does not unequivocally affect

the judged absolute size of coins, there is a relative accen-

tuation or overestimation of coins of varying denomination.

Accentuation in size estimation has further been

demonstrated to be the result of the attitudinal bias of S

(Carlson, 1960), the "symbolic value" of economically value-

less objects (Dukes & Bevan, 1952a) and the affects of reward

and punishment (Proshansky & Murphy, 1942; Schafer & Murphy,

1943; Smith, Parker, & Robinson, 1951; Solley & Engel, 1960;

Lambert & Lambert, 1953). All "autistic" experiments test

for the operation of functional factors or behavioral deter-

minants in response processes. However, as indicated, many

of the results in this area are equivocal due to the nature

of conceptual and methodological problems involved in demon-

strating motivational factors. Actually most of the research

on accentuation due to "value" has been criticized for ne-

glecting the role of the perceiver, for the artificiality of

experimental conditions, and for lack of adequate stimulus

control and inadequate empirical definition of terms (Luchins,

1950). This has led to a great number of studies going beyond

the simple accentuation hypothesis and the making of a closer

examination of the responding organism to see if selective

factors exist in visual process i.e. factors which would cause

one to attend to certain relevant objects in the environment

and not to others of lesser relevance. Thus Postman, Bruner

& McGinnies, 1948; McClelland & Atkinson, 1958; Vanderplas &

Blake, 1949; and Brown, 1960, give evidence for a selective

response process demonstrating to a large extent that one

sees what he wants to see or hears what he wants to hear.

Krechevsky (1938) has even concluded that there is evidence for functional factors influencing the structure of discrimination in animals.

As already mentioned, most of the previous research has shown that personally relevant objects are remembered to be larger than objects possessing no relevance for the perceiver. Perhaps some of the equivocality over the operation of motivational factors in the visual process can be removed by studying "value" along a different dimension. It would seem first that a visual dimension more fixed and less susceptible to memorial influence than size, such as number, might eliminate one source of uncontrolled variance (Minnaert, 1954). Second, "need" and "value" would seem to be expressed more directly as an increase in number than as an increase in size since the size dimension of Canadian coins increases in the dime, penny, nickel, quarter, half dollar order while value increases penny, nickel, dime, quarter, half dollar order.

Problem

Numerosity is that name given a response to the "manyness" property of a collection of items which an O or S can discriminate without counting (Stevens, 1951). It does not have connotations with respect to accuracy. Figure 11 shows numerosities found under experimental conditions employed by Jevons (1871) and Taves (1941). Note the increasing error with numbers greater than six (6). Subitizing is a term referring to that process governing "manyness" discrimination when small number is involved. This term has connotations with respect to accuracy. The skilled O shows subitization until a display exceeds 7 or 8 items (Hunter & Sigler, 1940; Casperson & Schlosberg, 1950; Miller, 1956); and the child and unskilled O to a limit of perhaps 4 items (Jevons, 1871; Glanville & Dallenbach, 1929; Sperling, 1960). Variables such as exposure time, intensity, size, area and density of objects have been shown (Hunter & Sigler, 1940; Karn, 1936; French, 1953; Kaswan, 1958; Teichner, Reilly, & Sadler, 1961; Teichner & Sadler, 1962; Kaswan & Young, 1963; and Porter & Wiseman, 1965) to effectively vary numerosity of greater number but to have no appreciable affect on subitizing. Subitizing just as numerosity is usually studied using timed exposure so as to preclude counting.

Counting is a procedure employed when "a class of objects or events occurs in a serial fashion or the events are so many as to preclude immediate discrimination" (Nelson,

& Bartley, 1961, p. 181). As such it is an entirely diff-
erent activity for ascertainment of "manyness" since it
involves employment of a human convention, namely a number
syntax.

"Value" is a complex term but it may be unambiguous-
ly defined within a modern monetary system. A study reported
by Ansbacher (1937) suggests that "value" is a dimension of
numerosity. Essentially his experiment determined that
numerousness of objects is a function of familiarity with the
monetary "value" of the object. Results showed that numer-
ousness increased for "value" objects with which Ss were
familiar but not for those objects whose "value" was unknown.
More valuable objects were reported in another experiment
to appear less numerous. In the experiment to be described,
displays varying along a "value" dimension and displays
varying along a "non-value" dimension will be related to
numerosity response.

Social, cultural, and motivational factors are appar-
ently related to visual discrimination of size (Bruner & Good-
man, 1947; Bruner & Rodrigues, 1953), weight (Dukes & Bevan,
1952b; Tajfel, 1959c), reversal of figure and ground (Smith
& Hochberg, 1954), absolute threshold (Solomon & Howes, 1951;
Johnson, Frinke & Martin, 1961), and object identification
(Sanford, 1937; McClelland & Atkinson, 1948). The present
study relates a combination of three variables to the dis-
crimination of number in displays possessing different levels
of "value".

The hypotheses tested are the following:

1. There will be no significant difference in numerosity response between two groups of children varying with respect to class membership, economic status and level of "need" when the number of objects on either the "value" or "non-value" continuum falls below the "span of discrimination" characterizing these subjects groups i.e. less than six (6).

2. Children from poor class, of low economic status and possessing "high need" will give higher numerosity responses than children from upper-middle class, of higher economic status and possessing "low need" when the targets displayed both possess "value" and are greater in number than the "span of discrimination" i.e. more than five (5).

3. There will be increased divergence between the numerosity responses of the two groups when the objects displayed possess value and increase in number beyond the "span of discrimination", i.e. more than five (5).

Method

Subjects

Forty (40) third graders without visual difficulties
and attending two public schools in the City of Edmonton,
Alberta were selected. Age was approximately normally
distributed within a range of 7 years 9 months to 9 years
5 months. Mean age was 8 years 6 months.

Selection was undertaken to provide two subject groups.
Group 1 is to be called "low economic". This group was
defined by (a) residence in a low income area of the city,
(b) identification by others of the individual as a member
of the class of the poor and (c) familiarity with the
purchasing power of money ("value") but without money
("means") being readily available. Group 2 is to be called
"high economic". This group differed from the "low economic"
on the basis of location of residence, class membership, and
availability of money. It was however identical to the
"low economic" with regard to knowledge of the purchasing
power of money.

These two groups were assembled using the following
specific procedures. Residence requirement was fulfilled by
choosing a large group of Ss from a school in a low income
section of the city and another from a school situated in
an "upper-middle" income area. Income data was taken from
records based upon a recent demographic study. Class
membership was established by teacher evaluation. Depend-

ing on the school location (i.e. "low" or "high" economic area of the city), teachers were asked to select from the larger sample representing income areas a group of children clearly belonging to "poor" and "well-to-do" classes.

Practical sophistication with respect to money was established. Individuals from the groups of children selected by the teachers were each tested. Part 1 of Table 1 gives the questions asked. Pictures (not shown here) of these items were also shown to $\underline{S}$s at the time they were to respond. Responses were scored + if $\underline{S}$ gave a "reasonably" accurate answer as to the expense of the various items. For example, such responses to question one as "bubble gum costs one cent", to question two as "candy bars cost ten cents", to question three as "pop costs twelve cents", to question four as "the knife costs one dollar", and to question five as "the doll costs two dollars" were all scored +. To ensure that all $\underline{S}$s may be considered equally familiar with "value" independent of socio-economic difference, all of the 40 $\underline{S}$s chosen scored + on all of the five questions.

Personal economic conditions were established using the questions of Part 2 in Table 1. Replies were again judged + or - using qualitative criterion. For example, question one responses such as "Mr. Jones can't afford to buy bus tickets", or question two responses such as "The little boy didn't get the dime because his mother didn't have one", or question three responses such as "Lucy didn't buy the crayons because they cost too much", or question

Table 1

Questionnaire

Part I

Questions to Determine the Familiarity and the Validity
of the Child's Concept of Money

(a) How much does bubble gum cost?
(b) How much does a candy bar cost?
(c) How much does a bottle of pop cost?
(d) How much does a knife cost?
(e) How much does a doll cost?

Part II

Questions to Determine the Personal Economic Condition of the
Children and the Extent to which Money could be
considered a motivator

(a) Mr. Jones doesn't have a car and he walks a long
way to work every morning even though the bus
stops right in front of his house. Why do you
think he walks to work?

(b) A little boy came home from school one day and
asked his mother for a dime. Did his mother give
him one? Why (did) didn't she give him a dime?

(c) Lucy went into a store to buy a big color crayon
set. The store clerk said it cost 50 cents.
Did Lucy buy it? Why (did) didn't she?

(d) Jack is going to have a birthday party on Saturday.
He asked his father and mother if he could have a
bicycle for his birthday present. Do you think
Jack got the bicycle from his mother and father?
Why (did) didn't he?

four responses such as "Jack didn't get the bicycle because it cost too much" were considered as indicative of a "need" for money. Plus (+) and minus (-) replies were tallied and the final groups were defined using the following criterion. "High need" were defined as those scoring + on at least 75 per cent of these questions (three out of four). "Low need" children were defined as those scoring + on no more than 25 per cent of the questions (one out of four).

In order to provide an additional parameter (information), the Ss selected were not normally distributed in intelligence. Ss in both groups were selected so that six from each school were of slightly above, eight of average, and six of slightly below average intelligence. Assessment was made on the basis of class performance, teacher evaluation and available I.Q. measurements.

Apparatus and Equipment

Research was conducted in all-purpose school rooms modified so as to produce an experimental setting without incidental illumination.

The apparatus is schematisized in Figure 1. It consisted of two units. One unit was comprised of a field stop, incandescent lamp light source, lens with adjustable focus, and a .2 neutral density Wratten filter. Light source output was controlled by means of a variac and was continuously monitored through a voltameter. The second unit consisted of a box fitted with a reduction screen
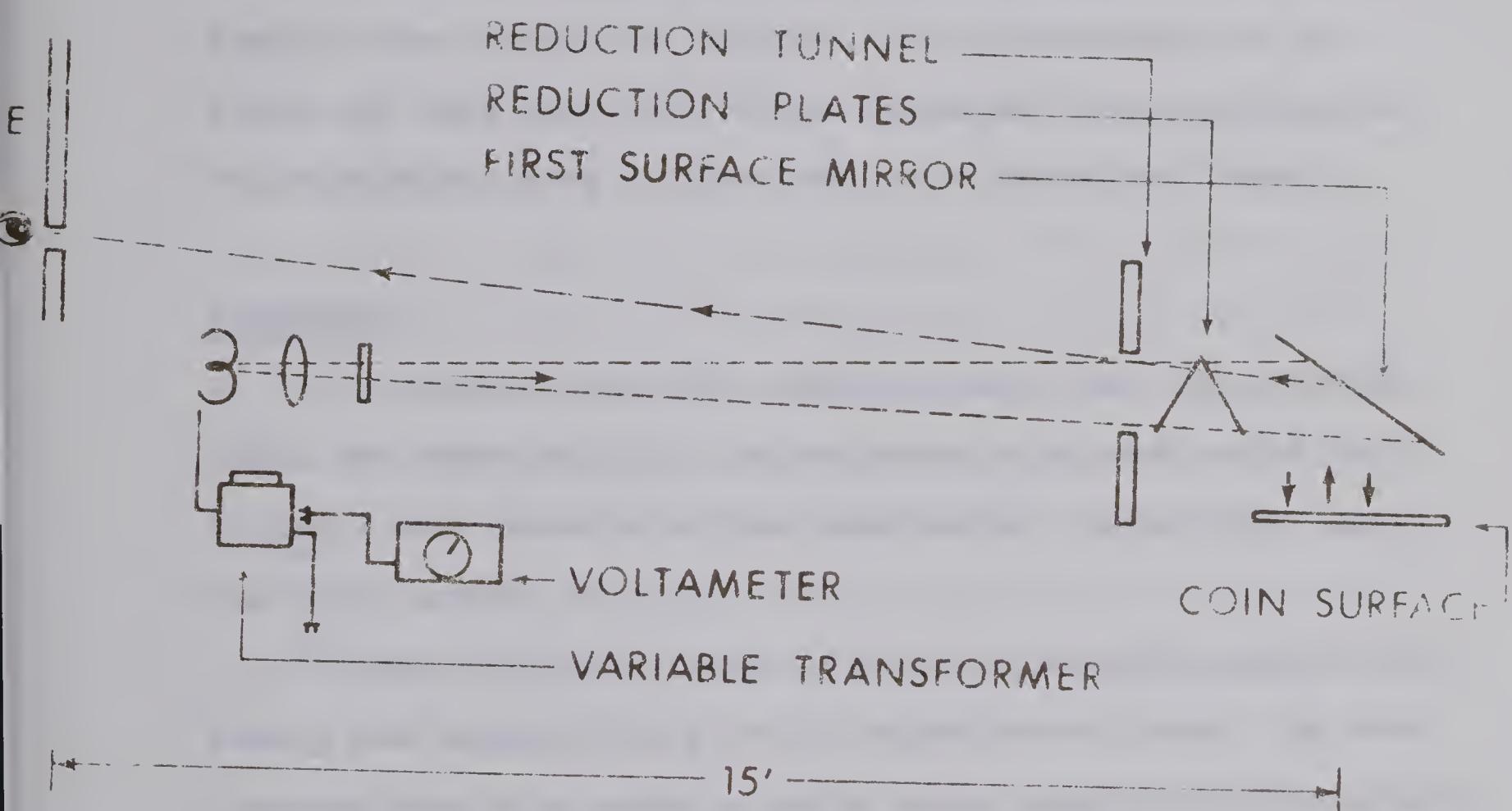
Figure 1   Schematic of apparatus. Distance from
eye to first surface mirror is 15 feet
as shown. Total visual angle subtended
by target surface was 1.9 degrees.

whose frame was coated with a luminescent substance, glass plates angled so as to reduce stray illumination from the projected light source, a mirror mounted so as to image the targets (slugs or dimes) on the frontal plane, and a black velvet target surface.

New Canadian dimes and aluminum blanks (slugs) of similar size served as targets. The reflectance of the slugs was less than that of the dimes and luminosities had to be equaled using a procedure to be described later.

Procedure

A general interview, during which time the questionnaire was administered, was conducted with each child prior to the actual running of the experiment. Seven days later the child served as a S.

Great care was taken in pre-experimental instructions. Each S was escorted by E to the experimental room. Ss were informed that they were to serve in an experiment determining "how well you can see". E continued conversation on site for approximately three minutes to put S to ease and then stated:

"This is an experiment to find out how well you can see how many things there are when they are shown for just an instant or flash". Immediately afterwards Ss were taken to a table on which a cloth was laid. The cloth was removed and S saw 25 slugs or dimes depending on the group S was in as will be described. E stated:

"Here are a lot of slugs (or dimes) that we are going

to play with. Before we start I want you to look at them closely to see that they are "only slugs" (or "real dimes"). Ss were allowed 30 seconds to inspect the slugs (or dimes) during which time they were permitted to handle the targets if they wished. No conversation transpired between E and S during this interval. The following instructions were then given:

"I am going to put some of these slugs (or dimes) down in this box. I won't put all of them in. Sometimes there will be only a few and sometimes there will be many". S next followed E to the box where the targets would be displayed and watched one being placed on the black velvet mat. Ss were asked to inspect the placement of the slug (or dime) on the mat and were shown the mirror which would let them see the slugs (or dimes) from their position of observation. S was then seated behind the reduction screen and instructed:

"You will only be able to see the slugs (or dimes) for a little while so I want you to sit on this chair and always look straight ahead through the hole in this box (field stop)".

Room lights were turned off and time was allowed for dark adaptation. After two minutes all Ss were able to detect without difficulty the blue luminescent square painted around the frame of the reduction tunnel. E then said:

"You should always look right at the center of the

blue square on the other box. When I say 'ready' I want you to look very hard because right after I say 'ready' I will show some of the slugs (or dimes). As soon as you see the slugs (or dimes) I want you to tell me how many you saw. You will not always be sure of how many there are because you will see them for just a flash. Remember, right after I say 'ready' I will show you the slugs (or dimes). Just as soon as you see them, tell me how many you think there were. Are there any questions?" Ss were then told they would be given one practice trial before the "game" would "really start". A two slug (or dime) pattern was shown and in all cases the Ss correctly perceived the display. Finally, a "now we will start" signal was immediately followed by an actual experimental target display. E continued to give "ready" signal before each presentation and required S to immediately report how many targets were shown. Inter-trial interval was approximately 30 seconds.

Individuals from both "high" and "low economic" groups assigned to the "value" continuum were exposed only to dimes throughout the entire procedure. Those assigned to the "non-value" continuum were shown only slugs. Thus four subject groups were employed: a "high economic" viewing dimes, a "high economic" viewing slugs, a "low economic" viewing dimes, and a "low economic" viewing slugs.

Random patterns of from three to twelve slugs (or

dimes) were always shown. <u>E</u> formed these on the black velvet mat by dropping the slugs (or dimes) to the surface. The only alteration made was to move all targets at least 1/2" apart and, in the case of the dimes, to make certain all display dimes were either "heads" or "tails". The "heads" or "tails" characteristic of the display was determined randomly.

As mentioned, while the areas were equal, reflectance from the dimes was greater than from the aluminium slugs. Since in the Bunsen-Roscoe Law Time and Intensity are reciprocal, it was necessary to reduce illumination for the dimes in order to keep luminance constant. The .2 neutral density filter and variac were used to cut down illumination while the luminance was equated by employing a McBeth illuminometer. The intensity of the slugs was set at 13.7 c.ft.^{2} The dimes were equated to this level by adding the filter and making a fine adjustment to the variac. This procedure minimized difference in spectral composition of the targets attributable to variations in temperature of the source.

The shutter was set such that it gave an exposure period of 40 milliseconds. Since exposure time was not an experimental parameter and intensities were low, no attempt was made to provide continuous field illumination between trials. The use of a brief exposure of low intensity precluded after-image counting.

The area which the projector illuminated was adjusted so that when the shutter was open an area about 7" by 6"

covering the 6" by 5" aperture on the face of the reduction
tunnel was lighted. The viewing distance provi.   ontal
visual angle of 1.9 degrees with each dime subtending 13 minutes
2 seconds of arc.

Ten orders of presentation were employed with one $\underline{S}$
in each of the four groups receiving one of these orders.
Each order contained each level of number from three to
twelve, three times. Appendix A contains a sample of the
data sheets used and illustrates various orders employed.

A total of 30 observations were recorded from each
$\underline{S}$ taking approximately 25 minutes. $\underline{Ss}$ were periodically
asked if they were tired or wanted to quit. In all instances
they said they wished to continue and seemed to maintain a
high level of interest throughout the entire experiment.

Results

One of the hypothesis being tested is that reliable differences in numerosity response will not occur between groups ("low" or "high economic") where the number of targets (slugs or dimes) does not exceed a critical number. Another hypothesis is that "value" targets produce a bias - in a constant direction - in numerosity response when the number of such targets exceeds a critical number. More specifically, that the "low economic" group will increasingly differ from the "high economic" group as the number of "value" targets (dimes) exceeds the discrimination power of the sensory pathway and that the difference will be in the direction of overestimation. No differences are predicted between the groups for "non-value" targets (slugs).

Data was analyzed graphically and also statistically by means of analysis of variance, trend analysis, and Duncan's Multiple Range. To make computation less cumbersome all raw response data were converted into "deviation scores" by subtracting number from numerousness. Nonconverted data is however presented in Figures 2, 11, and 12.

Figure 2 plots the relation between numerousness (judgment of the "manyness" of a display without counting) and number. Figure 2 shows the percentage difference between numerosity response and actual target number. It may be noted that (a) curves of both Figures 2 and 3 give little
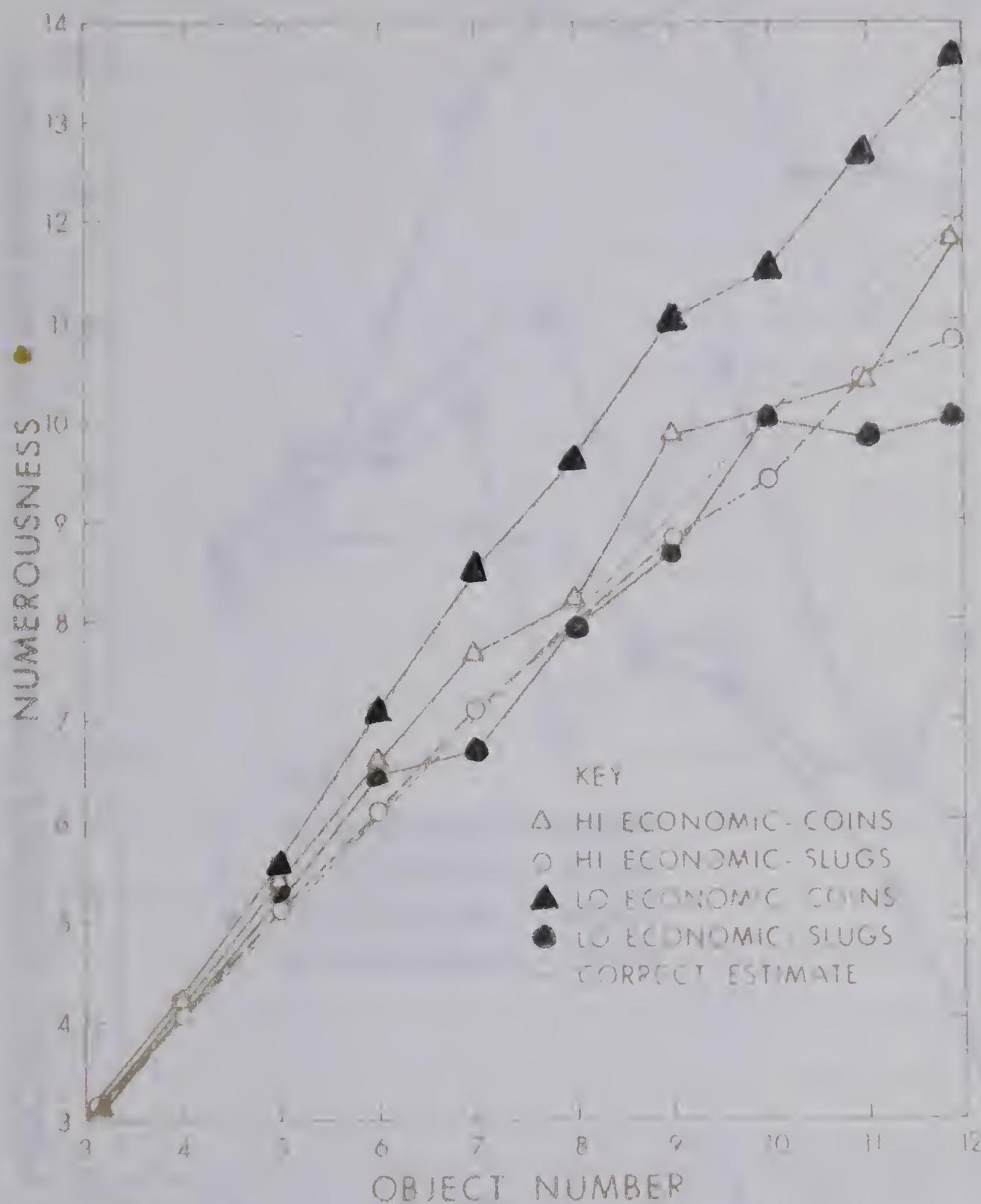
Figure 2   Numerousness shown as a function of
            number of targets. Responses from
   four subject groups are depicted
            (see Key).
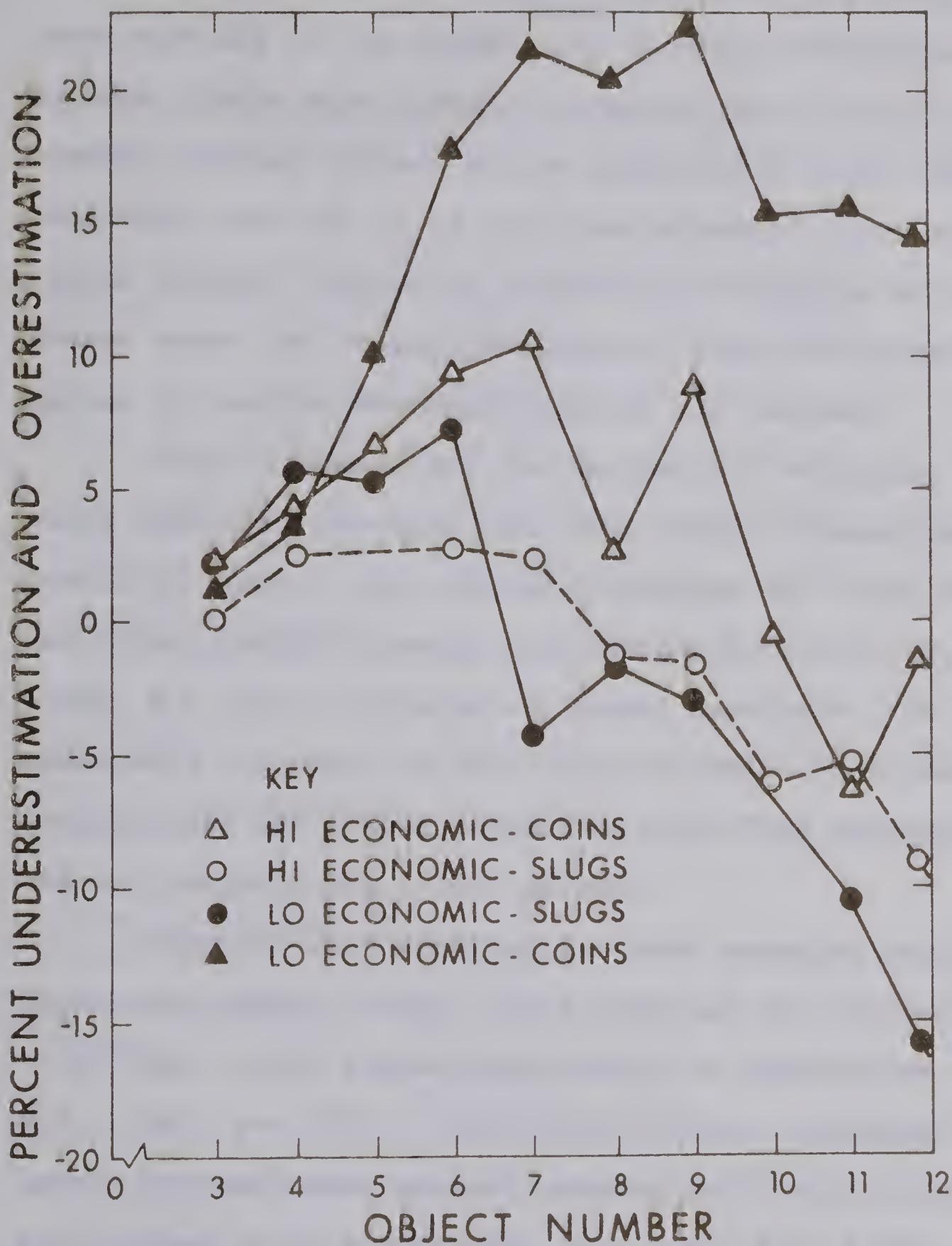
Figure 3   Percentage overestimation and underestimation
of target number. Responses from four subject
groups are depicted (see Key).

evidence for differences between conditions for target displays

less than six (6) in number, (b) sizable differences do occur

between groups when number is greater than five (5), (c) diff-

erences between subject groups appear only under the "value"

condition, and (d) it is the "low economic" group which gives

higher average numerosity responses to displays of greater

number under the "value" condition. Thus the primary data

appear to confirm the hypotheses in all respects.

Table 2 summarizes the analysis of variance. This

shows that when averaged over both "value" dimensions and

levels of number, the difference between the "high economic"

and "low economic" groups is significant (F = 17.62, d.f.

1,360, p < .005). In terms of actual magnitude, the mean

numerosity response for the "high economic" group was .0063

greater than the number shown while the "low economic" group's

average response was 1.0064 greater.

Dime and slug numerosities were averaged over economic

status and number levels. This resulted in a difference of

1.3663 and -.3535 respectively which is significant (F = 52.11,

d.f. 1,360, p < .005). Differences between responses to number

levels averaged over economic status and "value" dimensions

also proved to be significant (F = 2.12, d.f. 9,360, p < .025).

Numerousness is therefore reliably associated with number.

The only significant interactions found were "economic

status x value" and "value x numerosity". The fact that the

"economic status x value" interaction is significant (F = 16.23,

d.f. 1,360, p < .005) indicates that the differences in numer-

Table 2

Summary of Analysis of Variance for the Effect of "Value"
and "Need" on the Discrimination of Number

Source of Variation	Sum of Squares	d.f.	Mean Squares	F
"Economic Status"	25.0050	1	25.0050	17.6228**
"Value Dimension"	73.9342	1	73.9342	52.1076**
"Numerosity"	27.0723	9	3.0080	2.1199*
"Economic Status" x "Value Dimension"	23.0352	1	23.0352	16.2345**
"Economic Status" x "Numersoity"	14.9352	9	1.6595	1.1696
"Value Dimension" x "Numerosity"	37.5377	9	4.1079	2.9395**
"Economic Status" x "Value Dimension" x "Numersoity"	21.6810	9	2.4090	1.6978
Within Treatments (Error)	510.8053	360	1.4189	
	734.0058	399		

*p < .025
**p < .005

osity response between "high" and "low economic" groups are significantly different to "value" than to "non-value" targets. Thus economic groups respond significantly differently only when targets possess "value". The nature of this interaction is depicted graphically. Figure 4 plots differences between groups with respect to average numerosity deviation for "value" (dime) and "non-value" (slug) targets and shows how the average deviation of the two groups varies on each "value" condition. The "value" dimension appears important here since when slugs are viewed there is a small difference but when "value" is present the difference is considerable.

The significant interaction between "value x numerosity" (F = 2.94, d.f. 9,360, p < .005) suggests that the effect of numerosity is not independent of the "value" of the targets. This interaction is graphically illustrated by Figures 5 & 6 which plot average deviation on all the "value" and "non-value" number levels for the "high" and "low economic" groups. The fact that the differences in average deviations for the "value" and "non-value" number levels are different again reflects the significance of the "value x numerosity" inter-action. Differences in divergence of curves (Figures 5 & 6) suggests that "value" is less effective for those of "high" than for those of "low economic" status.

A finding which might be expected (but which may not be of special interest) is the significant heterogeneity of variance of the four groups over the levels of number (x^2 = 299.7, d.f. 39, p < .005). Response becomes increasingly
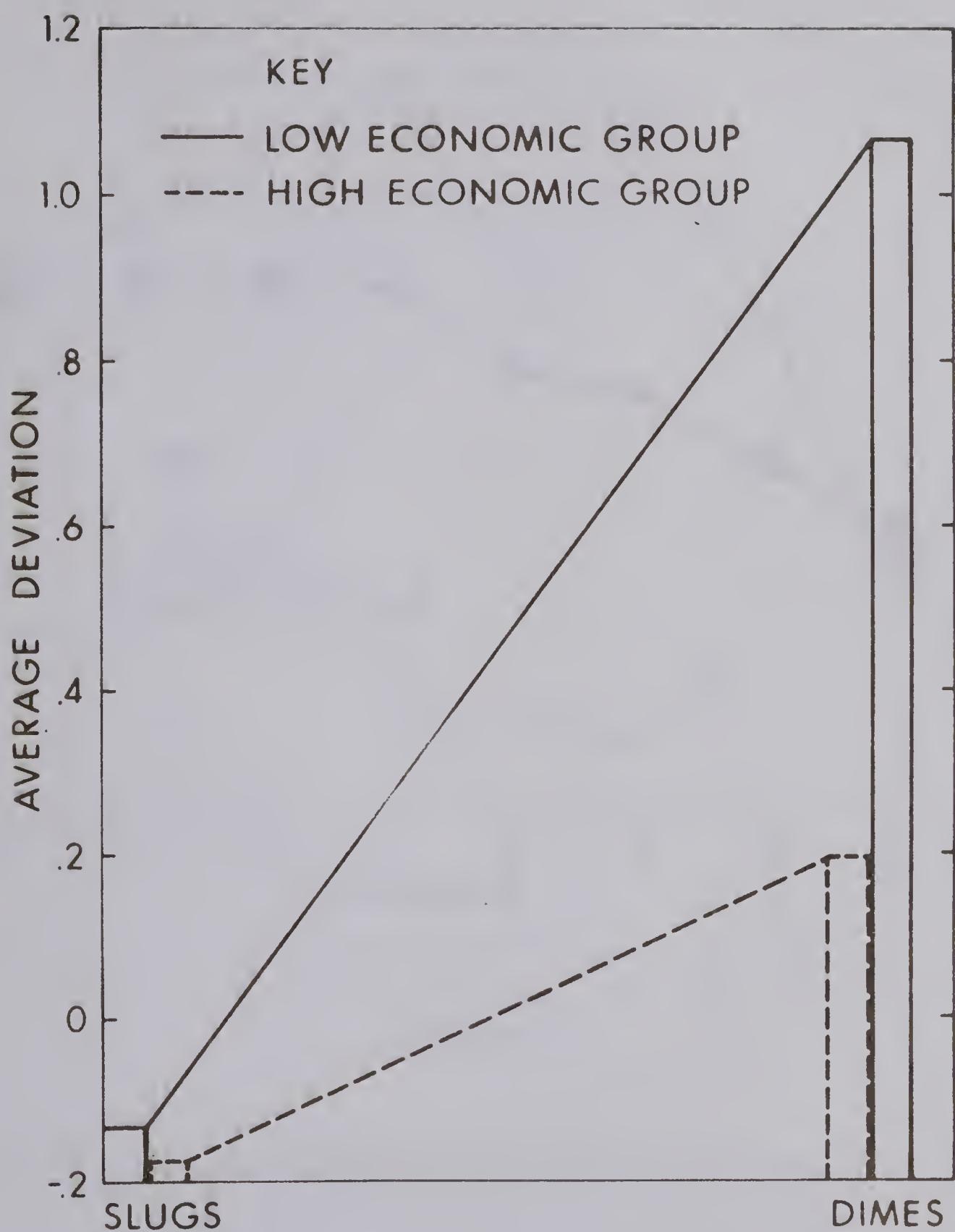
Figure 4   Data depicted have been transformed into
            "deviation scores" (see text) and averaged
            over all levels of number. Average deviation
            is plotted against "value" and "non-value."
            Responses from the major subject groups are
            depicted (see Key).
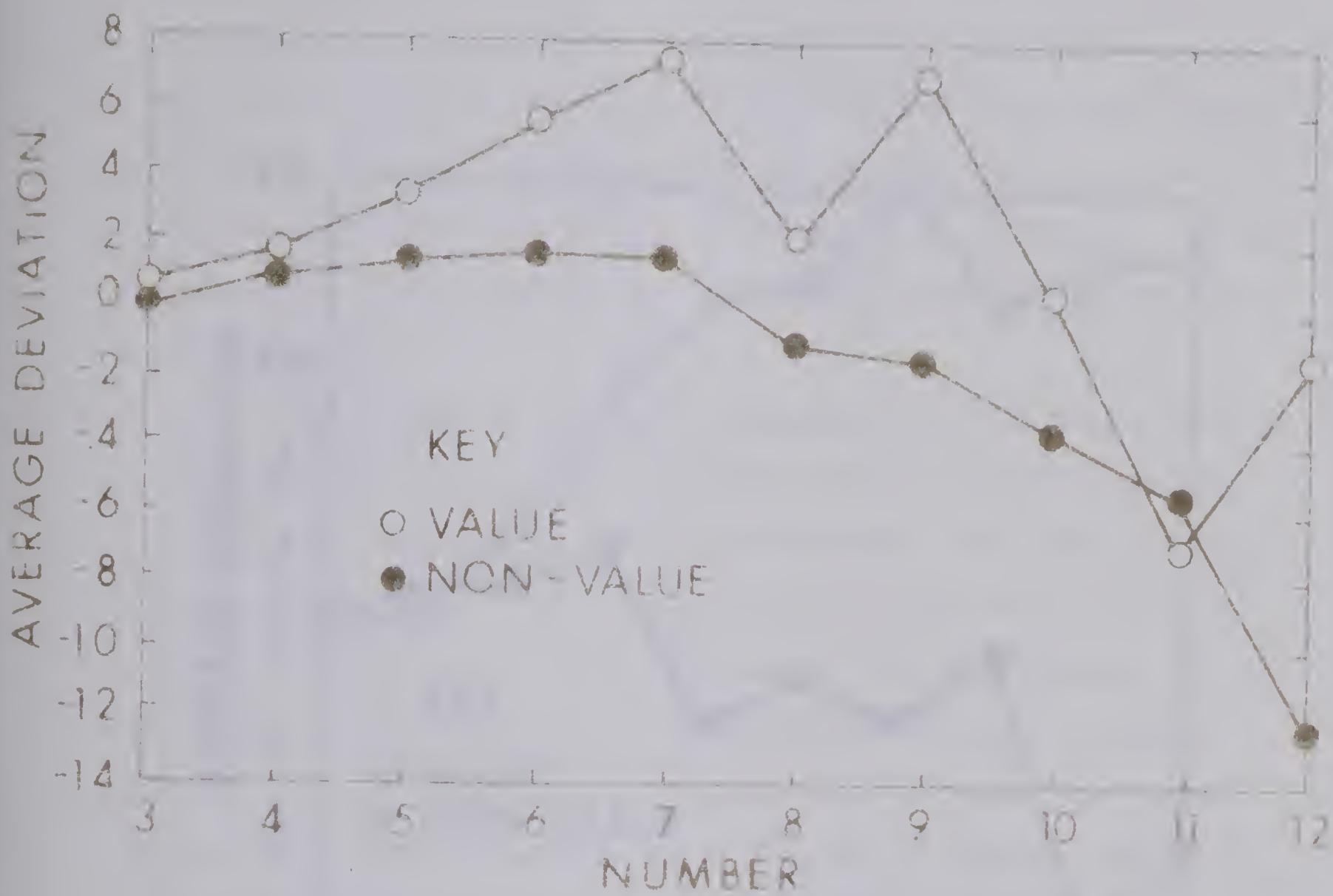
Figure 5   Data depicted have been transformed into
            "deviation scores" (see text). Average
            deviation of "value" and "non-value"
            numerosity responses are plotted against
            number. Only "high economic" group
            responses are depicted.
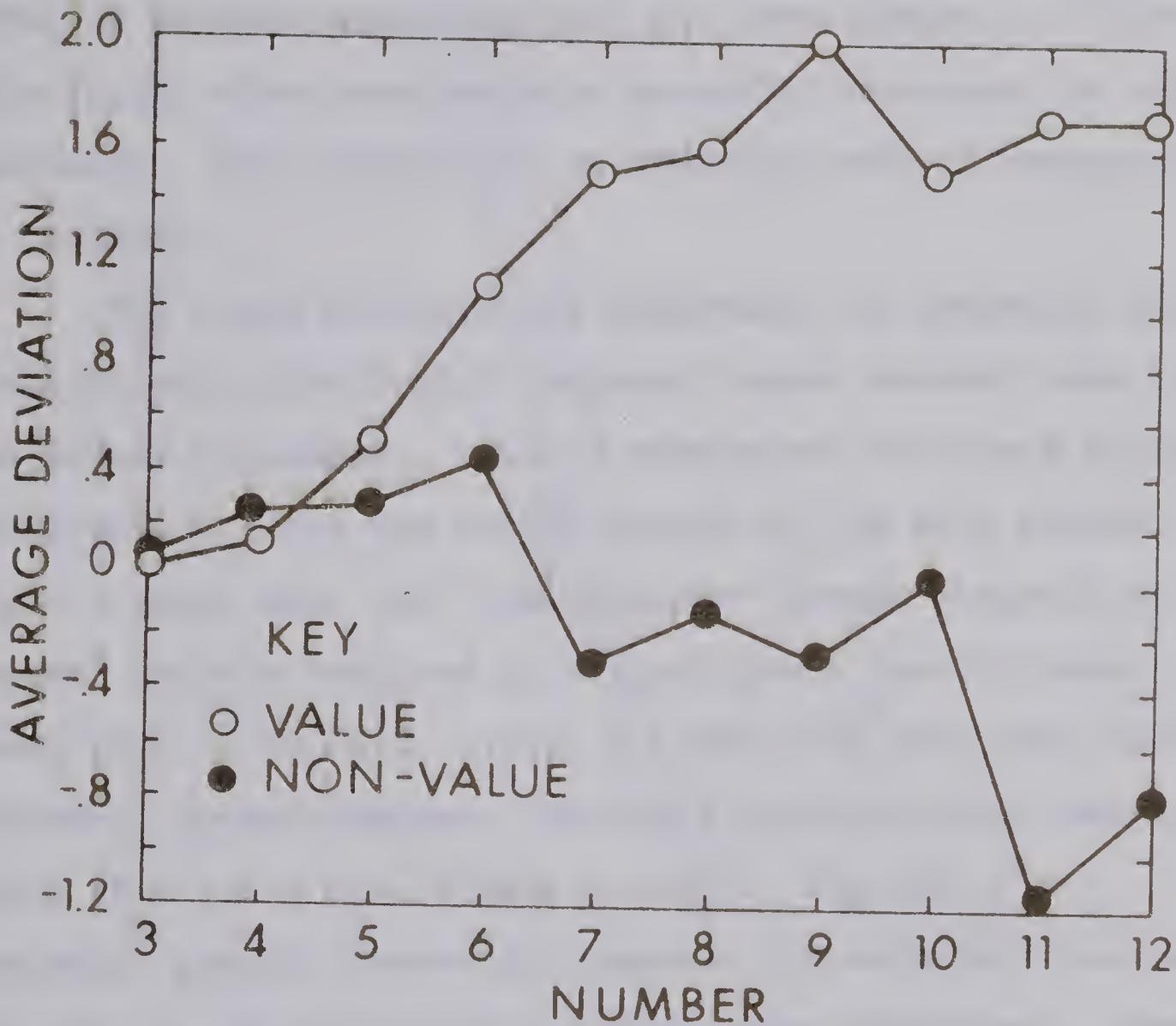
Figure 6   Data depicted have been transformed into "deviation
            scores" (see text). Average deviation of "value"
            and "non-value" numerosity responses are plotted
            against number. Only "low economic" group responses
            are depicted.

inaccurate as number increases. Figure 7 depicts the per-
centage of correct number responses by the four groups on
each number level and illustrates the fact that when number
is greater than six, less than 50% of the responses made by
all four groups were correct. The variances for each number
level is plotted separately for all four groups in Figure 8.
This Figure shows how variance generally increases as number
increases. This results in an over-all lack of homogeneity
of variance.

The trend analysis was undertaken to determine whether
statistically significant response trends existed over the
ten levels of number. Table 3 summarizes the trend analysis
and Figure 9 plots the actual trends of the four groups.
Table 3 shows that the "low economic" group's response to
"value" targets resulted in a significant upward linear
trend (F = 24.50, d.f. 1,360, p < .005) but that the "high
economic" group's response describes a significant quadratic
trend (F = 4.89, d.f. 1,360, p < .05). Thus the "low
economic" group's numerosity response progressively increas-
ed as the number of "value" targets were increased. Numer-
osity increased more rapidly than number. The "high economic"
group behaved differently. The average "high economic"
child increasingly overestimated until target number reach-
ed eight (8) and then showed a continual decrease in this
tendency until dime displays numbering eleven and twelve
were actually underestimated.

The trend analysis also showed that "low" and "high
economic" group responses to the "non-value" targets result-
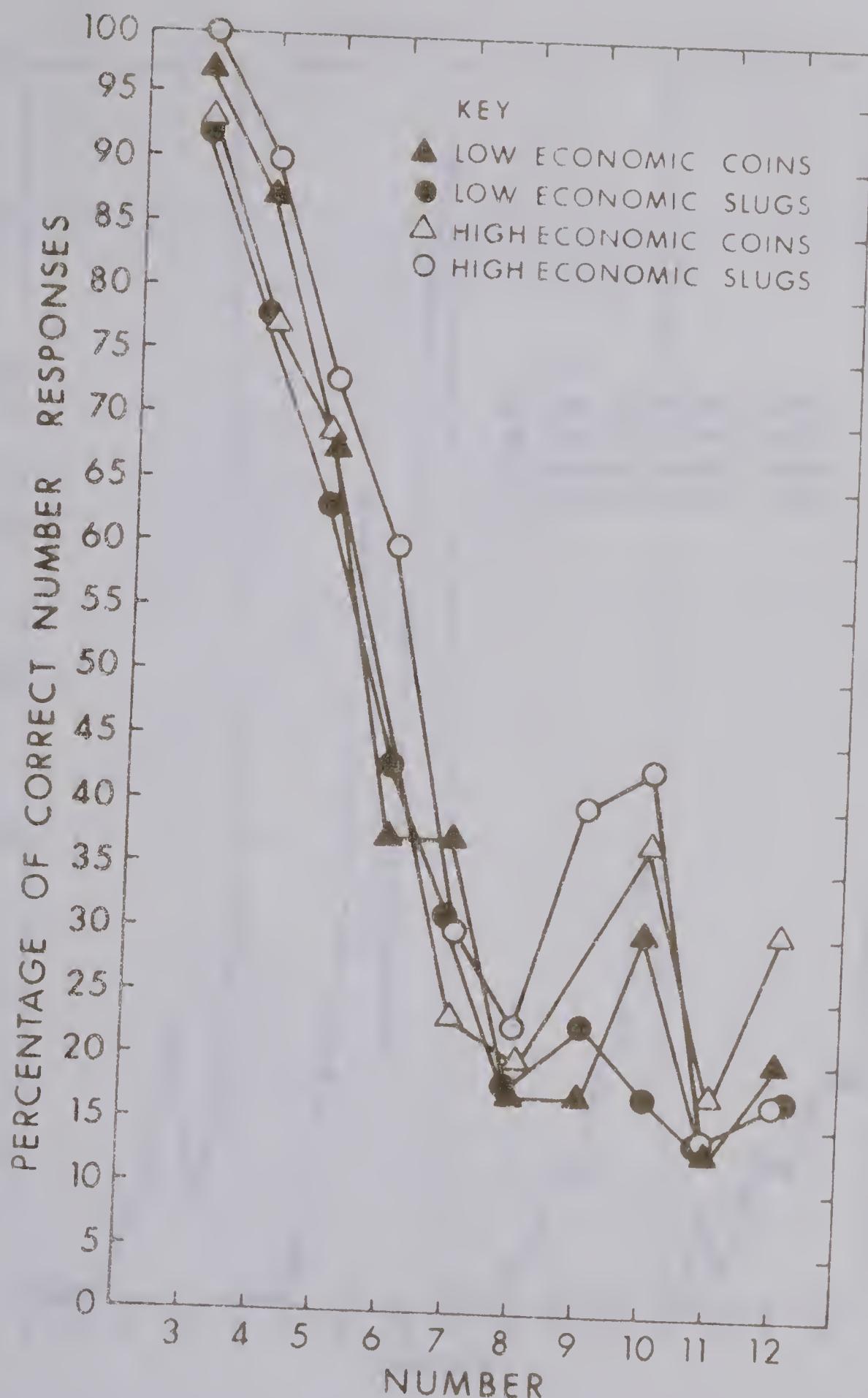
Figure 7   Percentage of correct number responses are plotted
against number. Responses from four subject groups
are depicted (see Key).
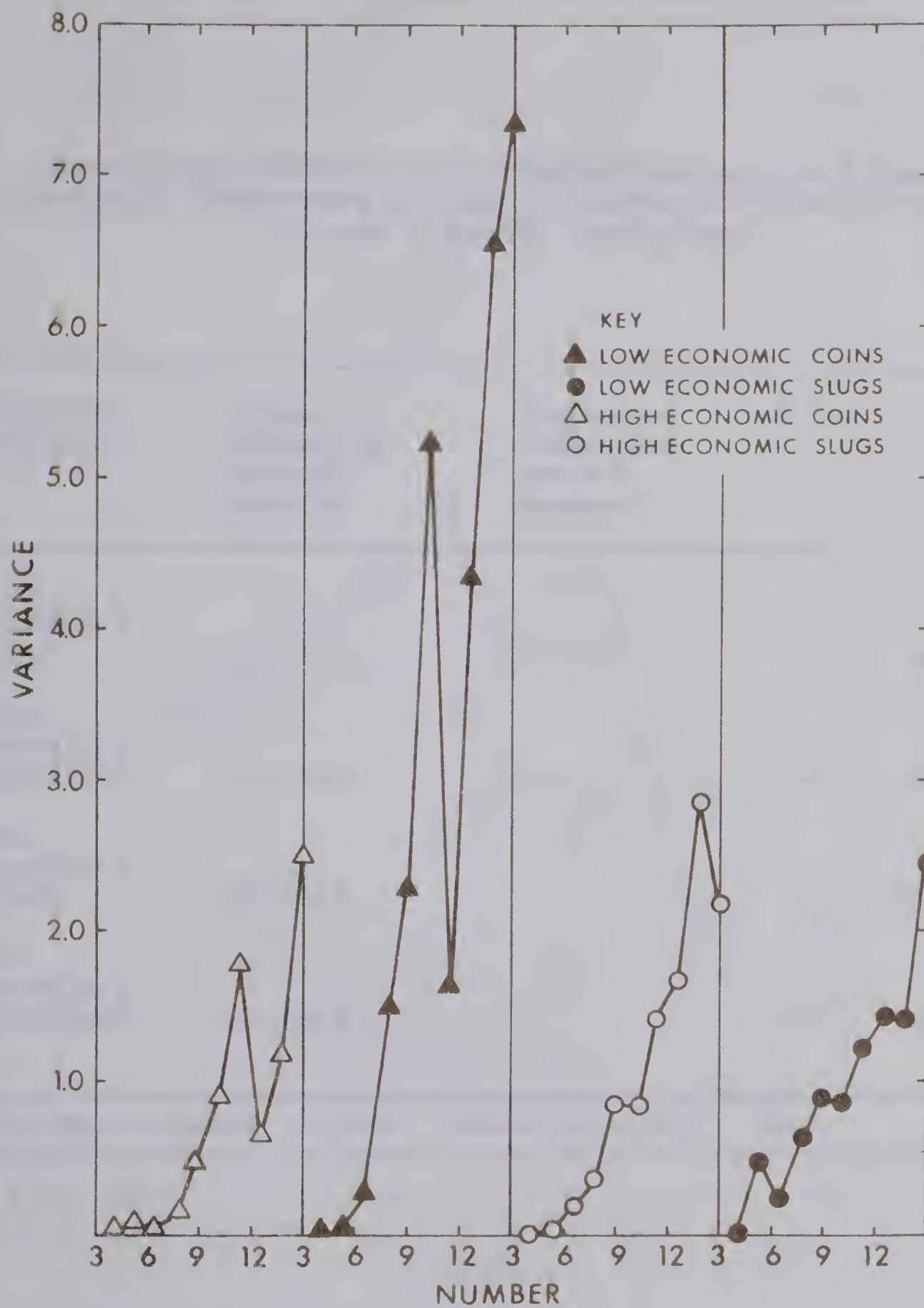
Figure 8   Numerosity variance plotted against number for
each of four subject groups (see Key).

Table 3

Summary of Analysis of Variance Showing the Linear and
Quadratic Components of the Interactions Between "Economic
Status x Value" Conditions

Treatment Condition	Linear Component Sum of Squares	Quadratic Component Sum of Squares	d.f.	F
"High Economic x Value"		6.9397	1	4.8909*
"High Economic x Non-Value"	11.5440		1	8.1358**
"Low Economic x Value"	34.7568		1	24.4955**
"Low Economic x Non-Value"	13.1823		1	9.2905**

Error Mean Square   1.4189   (From Table 2)   360

* p < .05
** p < .005
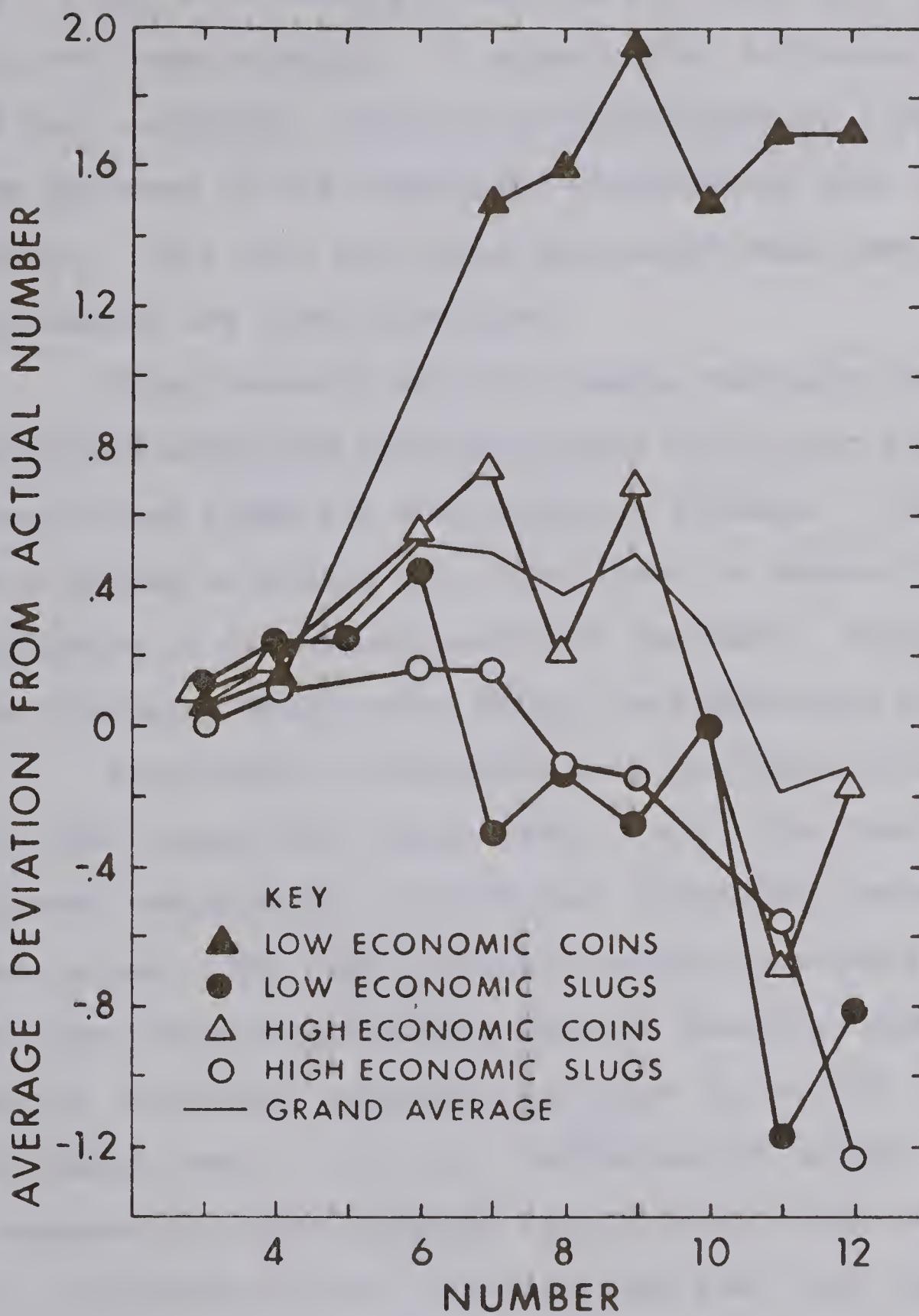
Figure 9   Data depicted have been transformed into "devia-
tion scores" (see text). Average deviation is
plotted against number. Trends of four subject
groups as well as the average trend are depicted
(see Key).

ed in significant downward or negative linear trends
(F = 9.29, d.f. 1,360 p < .005 and F = 8.14, d.f. 1,360,
p < .005 respectively). It appears that increased number
of the "non-value" targets was accompanied by a progress-
ive decrease in the numerosity responses by both economic
groups. This fact will have importance when theoretical
statements are later developed.

Using Duncan's Multiple Range, multiple comparisons
were made among the treatment means to further qualify the
results and allow for more explicit findings. Number levels
were paired in making the comparisons to reduce the possible
influence of the heterogeneity of variance. Table 4 contains
the treatment means among which the comparisons were made.

Significant differences were not found among any of
the four groups for number level 3 & 4. The level 5 & 6
however resulted in a significant difference between two of
the groups. The "low economic" groups numerosity responses
to dimes were significantly greater than the "high economic"
group's numerosity responses to slugs (R_4 = .581, p < .01).
At number level 7 & 8, the "low economic" groups numerosity
responses to dimes differed significantly from their numeros-
ity responses to slugs and also from the "high economic"
group's numerosity responses to dimes and slugs (R_2 = 1.02,
R_3 = 1.08, R_4 = 1.09, p < .01).

The trend established at level 7 & 8 continued. At
number level 9 & 10 still more reliable divergence between
the "low economic" group's dime numerosity responses and the

Table 4

Treatment Means for Each of the Four Subject
Groups on the Five Levels of Numerosity Used
in Duncan's Multiple Comparisons

Numerosity Level	"High Economic" Dimes	"High Economic" Slugs	"Low Economic" Dimes	"Low Economic" Slugs
3 and 4	.1165	.0495	.0820	.1990
5 and 6	.4495	.1500	.7845	.3505
7 and 8	.4570	.0325	1.5490	-.2165
9 and 10	.3660	-.2660	1.7495	-.1330
11 and 12	-.4335	-.9000	1.7000	-.9835

other three groups occurs (R_2 = 1.21, R_3 = 1.26, R_4 = 1.29,

p < .005). The differences occurring at the highest number

level (11 & 12) are most reliable of all (R_2 = 1.94,

R_3 = 2.01, R_4 = 2.06, p < .001).

Figure 10 plots the average deviation for each of

the four groups on each of the five paired number levels.

It illustrates the divergent tendency of the "low economic"

group's numerosity responses when "value" is involved.

As previously mentioned (subjects section), different

levels of intelligence were used with an equal number of $\underline{S}$s

from each level being randomly assigned to each of the four

groups. Dealing only with the "low economic" groups "value"

responses, it was found that the "high average" $\underline{S}$s assigned

to this condition had an average total overestimation of

13.55 dimes, the "middle average" of 10.08, and the "low

average" of 12.11. When averaged across the four group

conditions, the "high average" $\underline{S}$s had an average total over-

estimation of 3.94 targets, the "middle average" of 2.17,

and the "low average" of 2.83. A Friedman two-way analysis

of variance by ranks shows that intelligence, when averaged

over all four groups, did not exert any significant effect
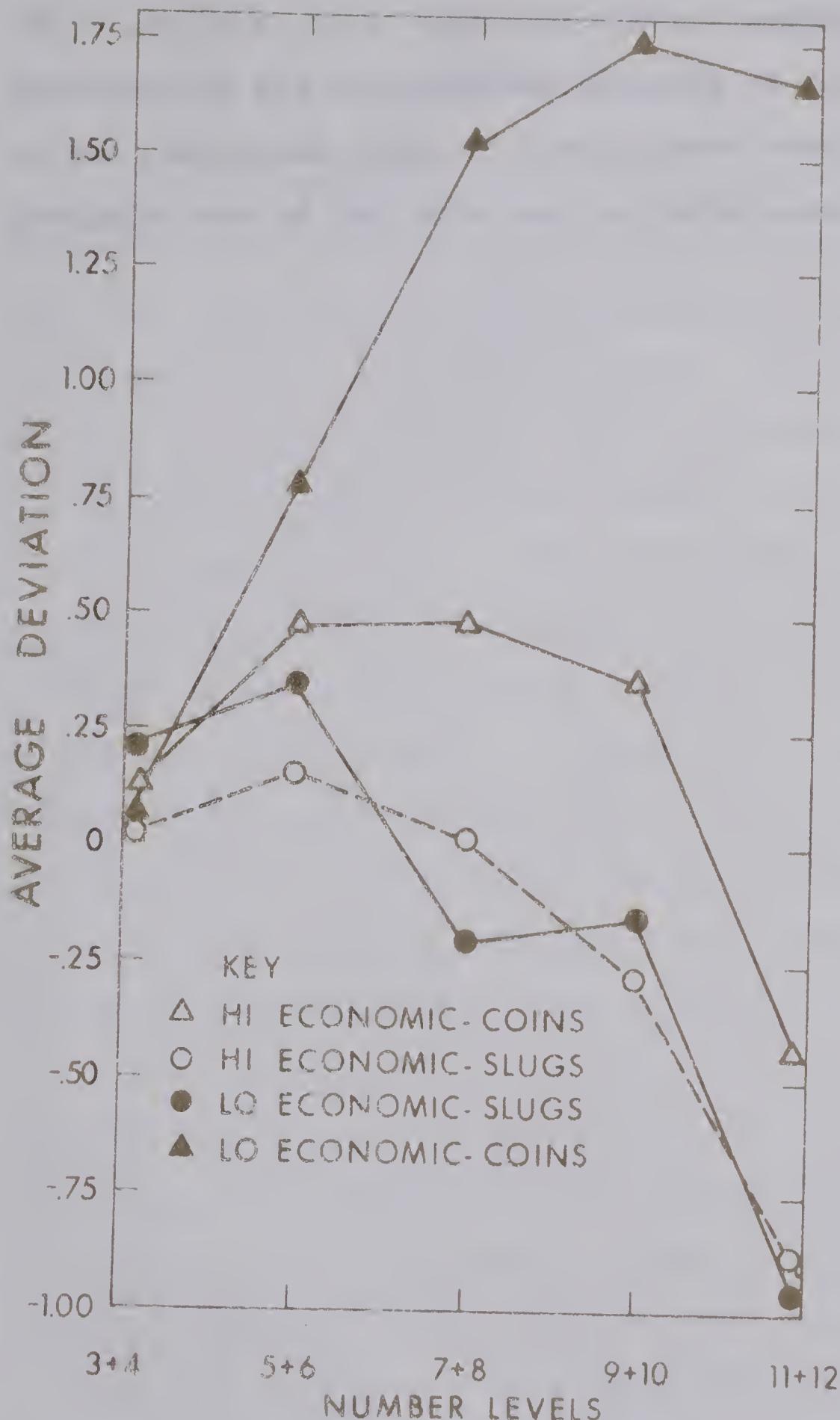
Figure 10   Data transformed for purposes of Duncan's
Multiple Range. Average deviation plotted
against five categories of number. Responses
from four subject groups are depicted (see
Key).

$(X^2 = .50$, d.f. 2, p .90). No further evaluation or inter-
pretation of the intelligence variable is felt necessary due
to the restricted range of intelligence sampled and the
possible lack of its valid and reliable assessment.

Discussion

The structure of the present results may in part be ascribed to criteria governing subject selection, i.e. empirical definition of subject samples on basis of need, class membership, and economic status. The critical studies of Bruner & Goodman (1947) and Carter & Schooler (1949) defined subject groups a-priori on the basis of place of residence only. Other researchers as Gilchrist & Nesberg (1952), Lambert & Lambert (1953), Lambert, Solomon & Watson (1949), Levine, Chein & Murphy (1942), McClelland & Atkinson (1948), Minture & Reese (1951), Proshansky & Murphy (1942), Rock & Fleck (1950), Sanford (1936), Sanford (1937), Shafer & Murphy (1943) Smith & Hochberg (1954), Solley & Engel (1960), used solely operational consider-ations in defining motivational properties of $\underline{S}$[5].

The results from the present study also seem to depend considerably upon the identification of "value" as a number property. Our treatment defined "value" as a ratio scale. In contrast, previous research Bruner & Goodman (1947) and Carter & Schooler (1949), Dukes & Bevan (1952a) used size as a measure of "value". The relationship between size and "value" seems tenuous at best with nickels being smaller than quarters but larger than dimes. And even if one were to exclude the dime from consideration the relation would be ordinal and the continuum limited to coins.

Results indicate satisfactory conformity of data to prediction. It is proper therefore to proceed to a discussion of theoretical and systematic issues touched upon in the introduction. A theoretical issue which has received considerable impetus through Allport (1955) and Pastore (1949) is whether "value", "need" and other so-called behavioral determinants directly affect primary sensory (neurophysiological) processes or whether they assert their affect through cognitive processes.

One thing seems clear. Since when number was less than six (6) subject groups differing with respect to socio-economic status did not differ in numerosity response nor did average numerosity vary with target type, the same process controlled discrimination of number for all groups. With number less than six (6) an "identical" or 1:1 relationship exists between numerousness (R) and number (S). A log-log transformation of numerosity responses and number levels is plotted in Figure 11. This Figure illustrates that when number is less than six (6), $R = f(S)$. It can be seen that this condition holds for both curves representing the average slug numerosity responses averaged over both "high" and "low economic" groups and the average dime numerosity response of the "low economic" group (see Key, Figure 11). Using Allport's (1955, pp. 345-357) terminology, one may therefore say that variations in cognitive or means value (degree of "positive relevance" an object has in a need-fulfilling situation) or variations in end value (degree of "motivational
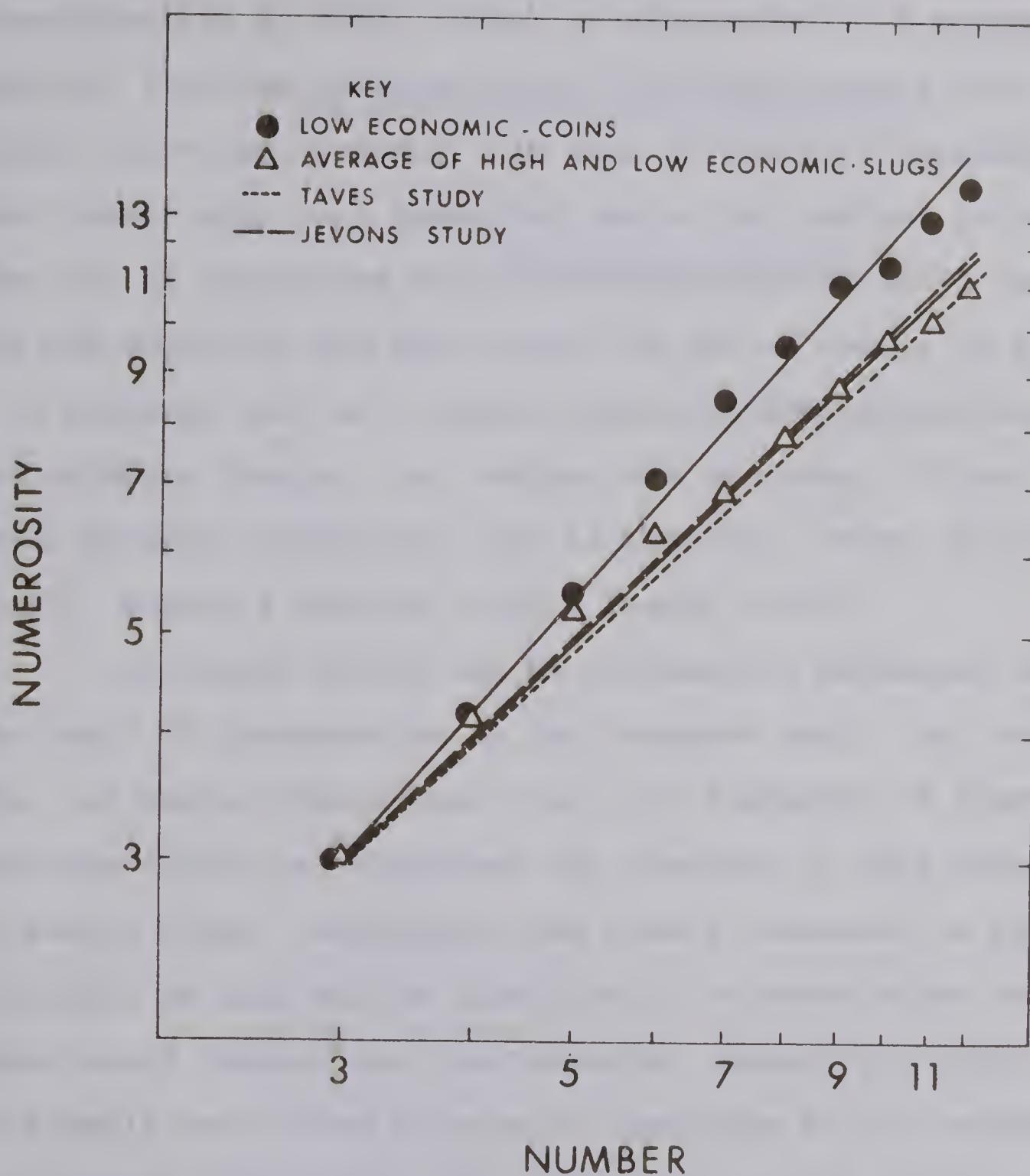
Figure 11 Log-log plot of numerosity as a function of number.
Responses from two subject groups are depicted.
Results from research of Jevons (1871) and Taves
(1941) are also fitted using free hand technique.

involvement" in a need-fulfilling situation) produced
no effects under such conditions.

It seems entirely plausible to suggest that accurate
discrimination of small number or subitizing is a psycho-
physical function governed only by activity taking place
within the visual pathway. As such it would be dependent
upon number only as a labelling device for nominal purposes.
That is, in suggesting that discriminations of small number
are non-cognitive one must treat the use of number by the
S in response only as a simple naming or categorization of
the stimulus display i.e. nominal use of number. There is
ample evidence suggesting this is possible (Price- Williams
(1962), Nelson & Bartley (1961), Piaget (1952)).

The Bunsen-Roscoe law is customarily explained on
the basis of transduction in the receptor cell, i.e. conver-
sion of photic energy over time into frequency of discharge.
Hartline (1934) has confirmed the presence of this process
by making direct recordings from visual receptors in Limulus.
Difficult as this may be intuitively, it seems clear that
where small numbers are discriminated, numerosity response
is totally controlled by rate of discharge in the receptor
cell system (see Figure 13). Nelson & Bartley (1963) Nelson,
Bartley & Jewell(1963) have produced a neurological explanation
of the Bunsen-Roscoe law, brightness and size discrimination
that includes but goes beyond sense-cell phenomenon. Although
their explanation of the role of limiting temporal conditions
in formation of contour processes is relevant here, it is too
detailed for consideration.
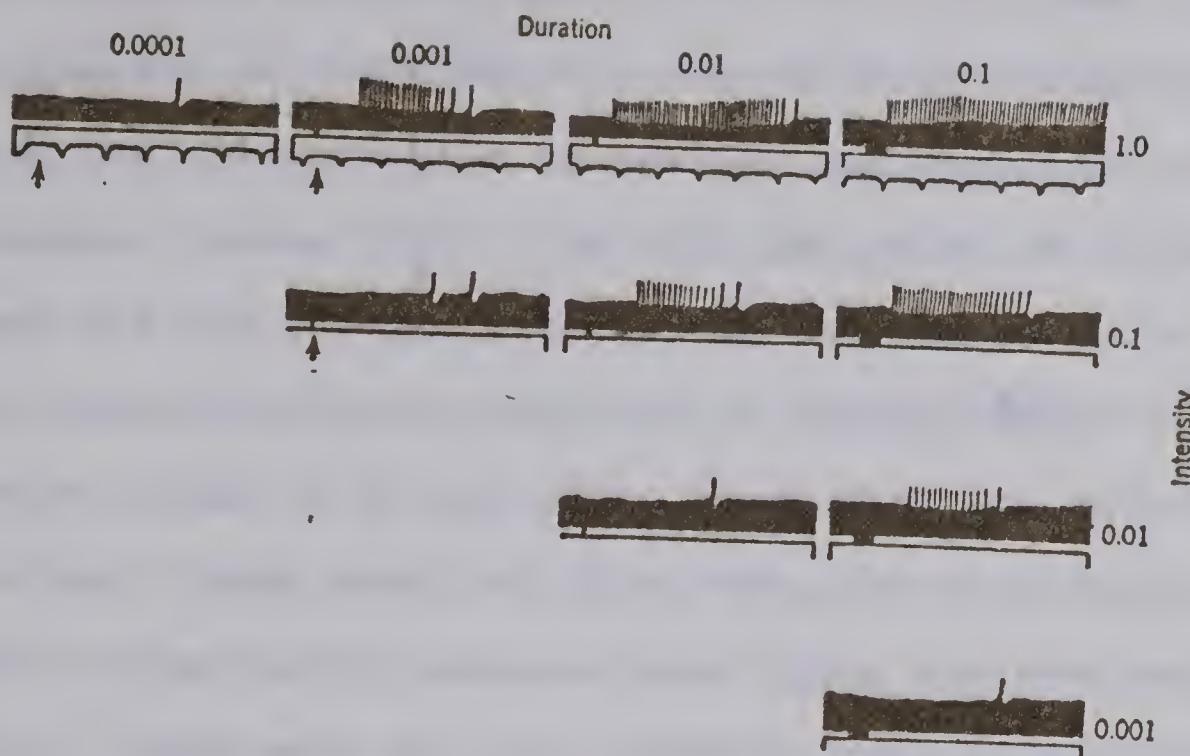
Figure 13 Oscillograms depicting bursts of impulses in a single optic nerve fiber of a horseshoe crab in response to short pulses of light under varying Intensity (I) and Time (T) conditions. Relative intensity ($1.0 = 3 \times 10^6$ meter candles) is given on right. Duration of pulse (in seconds) is given on top. Position of signal for short pulses are marked by arrows.

Displays having greater than five (5) items show a discontinuity of function as a rather abrupt divergence between the curves begins at six (6) and continues up and through twelve (12). Six (6), the point of deflection between the two curves, may thus be considered to be the origin where factors in addition to sensory factors become operative since it is the point where the "low economic", poor class, "high need" children begin to significantly differ in numerosity response when dimes are involved as targets. Below six (6) (i.e. within "span of discrimination"), number discrimination is handled solely by sensory pathway, but above six (6) this process is insufficient as shown by the breakdown of veridical discrimination. Discrimination of greater number is therefore not actually a psychophysical function but dependent upon factors in addition to number, in this case presumably motivational or cognitive properties of the responding organism. This distinction parallels the previously made distinction between subitizing and numerosity.

Thus there appears to be clear evidence for the operation of at least two mechanisms in the discrimination of number, one for small number and one or more mechanisms for greater number. Recognizing that number responses are different when they refer to subitizing processes then when they refer to elements within a highly developed number syntax, Kaufman, Lord, Reese & Volkman (1949) and Jensen, Reese, & Reese (1950) sought to explain how discrimination

of displays of large numbers of items takes place. The use
of number for more complex displays would, following their
line of analysis, reflect the use of number as a description
of position within an ordered relation. Thus one could say
that when dealing with greater number, human responses involve
ordinal, interval, or ratio scales and hence judgmental
processes. But, there is also the possibility to be recog-
nized that number may be a nominal name for a pattern discrim-
ination or refer to non-formalized cognitive structure provid-
ed by individual past experience. In any case there is little
dispute that motivational factors will affect judgmental
processes and thus include responses based upon counting,
number, or pattern estimating of a display (numerosity) made
under limiting time conditions.

Motivational theorists have gone further however in
relating motivation and judgment. Judgmental processes have
been cited as the sole process upon which behavioral deter-
minants act (Chein, Lane, Murphy, Proshansky, & Schafer, 1951;
Pastore, 1949; Allport, 1955). While subitizing clearly has
a sensory explanation it seems that to deny or entirely
exclude the judgmental process from numerosity response
would obliterate a distinction demanded by data. Since
numerosity response involves very brief time exposures for
which after-images can be eliminated they seem to provide
a condition within which S relates an uncertain discrimin-
ation to a number syntax. In agreement with the hypothesis
of Murphy, Proshansky and others, it seems difficult to see

how numerosity response made by our S̲s̲ may be considered

independent of judgment. However, even though judgment and

other cognitive processes do appear to be involved it also

seems fallacious to consider numerosity response as synony-

mous with judgment.

It would appear that we are discussing a response

type frequently identified as perception. Perception accord-

ing to Bartley (1958) is an immediate discrimination and to be

distinguished from judgment; judgment considered to be a

terminal reaction following a series of primary sensory or

perceptual responses. Such categorization is in keeping with

distinctions between subitizing, numerosity and counting

sequences our data seem to require, but it is still necessary

to have more complete and explicit means than Bartley provides

for recognizing membership in the class of responses he calls

perception and judgment. Our preference is to separate

cognitive features embodied in past experience from those

related to formal ways of thinking (logical or mathematical

syntax) and to restrict the term judgment only to the latter

category leaving perception identified with individual

("past") experience. "Immediate" we interpret to refer to

situations in which response is contiguous with stimulation.

Hence numerosity response is to be related to variables

operative in both judgmental and perceptual processes but not

to be totally identified with either.

Temporal factors are involved in each of these

response realms. Therefore usable distinctions can perhaps

be drawn on this basis. Judgment, as previously mentioned,
can be considered a result of a series of responses involving
fixed cognitive frameworks and perceptual response a result
of a comparison of items existing contiguously in time
(immediate responses), the comparison involving past experience.
Sensory and perceptual processes share this aspect of immed-
iacy but sensory and perceptual response classes are to be
distinguished on the basis that perception reflects the
integrative action of a nervous system functionally modified
by specific previous stimulation. Perception thus has symbolic
significance as a critical feature while sensory response makes
reference to processes which can be explained in terms of
events taking place within a single tissue system without
reference to cognitive frameworks.

The results may be also treated theoretically employ-
ing quantitative techniques. Numerousness, the judgmental
response (R), is always at least partly a function of number
the stimulus (S). By expressing this relationship quantitatively
in terms of $R = cS^m$, where "c" is an arbitrary coefficient
reflecting unit of measurement, and "m" is the actual inclin-
ation of the slope, (Fig. 11), it is possible to give algebraic
meaning to the slope and so express differences in numerosity
response as a function of motivational factors. The slope of
the average slug numerosity responses is best satisfied by
$R = 1.157S^{.919}$ where the two unknowns "c" and "m" were simul-
taneously solved for. The exponential value obtained signifies
a slight deviation from linearity (unity) and indicates numerousness

to increase less rapidly than number. This corresponds well
to the previous findings of Jevons (1871) and Taves (1941)
which are shown in Figure 11. On the other hand, the
equation $R = .904S^{1.119}$ describes the slope of the "low
economic" group's average dime numerosity responses. The
exponential value here again signifies a slight deviation
from linearity (unity) but indicates numerousness to
increase more rapidly than number. Differences in magnitude
between the two exponents may be taken to quant-
itatively describe the influence of motivational factors.
The value of "c" in these two equations is not of special
concern; differences in "c" reflect the fact the equations
were solved for all levels of stimulation (number of target
items). Differences in the value of "c" would be greatly
reduced if the equations were fitted just to data from
displays of six (6) and more in number, i.e. the numerosity
data and not numerosity plus subitizing data.

The extent to which motivational properties influence
number discrimination can also be expressed geometrically in
terms of the angular separation between the regression lines
fitted to Ss responses. Figure 12 illustrates the regression
lines fitted to the slug numerosity responses averaged across
both "high" and "low economic" groups and to the dime numer-
osity responses of the "low economic" group. Figure 12 also
gives the equations for predicting numerousness (Y) from
number (X) under the "value" and "non-value" conditions.
The angular separation between the regression lines was
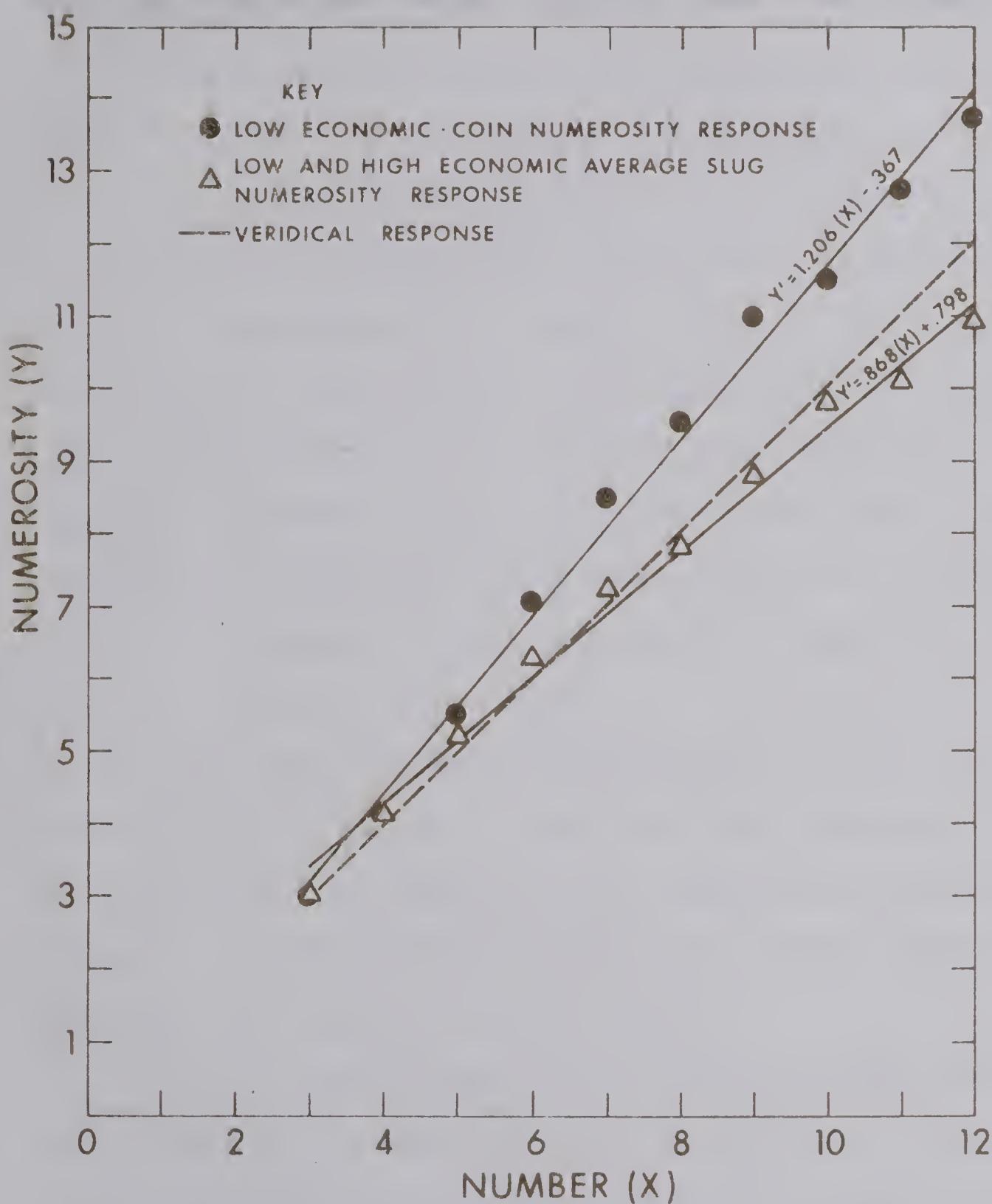
Figure 12   Best fitting curves and formulas for unconverted
response data. Responses for two subject groups
are depicted (see Key).

determined to be approximately 10 degrees with the "value" regression line again being slightly greater than linear and the "non-value" being slightly less than linear.

Summary and Conclusion

Two levels of "value", two levels of socio-economic status ("need") and ten levels of number were combined into a 2 x 2 x 10 factorial experiment with repeated measurements to determine if motivational factors are effective in a child's discrimination of number. Half of the children in each of a "low economic" and "high economic" group (empirically defined) were briefly shown displays of economically valueless slugs varying in number from three (3) to twelve (12) and half were shown displays of dimes varying in like manner. Thus four subject groups were employed: one "low economic" shown dimes, one "low economic" shown slugs, one "high economic" shown dimes, and one "high economic" shown slugs. A constant time (exposure) period falling within the limits of the Bunsen-Roscoe law was used so as to have stimulation (number of targets) both within and behond Ss "span of discrimination".

It was found, under these temporal conditions, that when number is greater than five (5) the "low economic" group numerosity responses to displays of dimes differs significantly from the three other groups. This difference increases in reliability as the number of display objects increases from six (6) to twelve (12). Results confirmed expectations. It was concluded that the judgmental processes of a child involved in number discrimination may be function-

ally modified by the existence of certain motivational

factors but that response controlled by processes of the

visual pathway are relatively unaffected. Results were

related to sensory, empirical and motivational theories

of visual phenomena.

Footnotes

[1] These "spans" are often considered synonymous in the
literature, but Oberly (1921) does make legitimate
distinctions between three of them in terms of threshold
value. On the basis of introspective characterizations
of Ss, Oberly concludes that threshold values are
"greatest in magnitude for apprehension, intermediate
for cognition, and smallest for attention". In line
with distinctions to be put forth in the discussion of
this thesis, it is suggested that sensory process is
involved with "span of attention" and that motivational
factors may be involved in "span of apprehension".

[2] One significant investigation is that of Price-Williams
(1962) who reported that members of (primitive) societies,
whose culture is devoid of number syntax, could discrim-
inate additive relations possessed by items. Another
relevant study here is that of Piaget who illustrates in
The child's conception of number (1952) how the develop-
ment of arithmetic concepts in children is related to and
dependent upon natural sequences of development. A myriad
of other studies have appeared as a result of applied
investigations aiming to establish educational procedures
for developing mathematical notions.

[3] Solley & Murphy in Development of the perceptual world (1960)
suggest that this definition could be improved by the
qualification that the need satisfaction be immediate.

[4] It is widely agreed that autism is also in large part
dependent on the "socialization process" (Murphy 1947;
Piaget, 1930) in that children who could be considered
more "socialized" due to environmental conditions are
generally less autistic than are children from "socially
impoverished" environments. This is in line with Piaget's
definition of autism in that the "more socialized" children
would have a "more realistic" cognitive idea of reality
and thus would be less likely to confuse truth with desire.

The study of Siipola & Hayden (1965) however causes one to
question the extent to which autism is related to the
"socialization process". They found that a sample of
retarded children (who because of the nature of their
handicap may be considered "less socialized") had a
significantly greater number of children possessing
eidetic imagery (non-autistic perception) than a sample
of normals.

[5] Presence of operationally induced motivation is based upon
the actions the experimenter takes during the experiment in
contrast to those present "naturally" or through non-exper-
imentally induced processes.

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Appendix A

Data Sheets illustrating orders

of presentation of targets.

ORDER 1	ORDER 2	ORDER 3	ORDER 4
8	11	5	12
6	6	9	5
9	5	9	10
4	8	3	7
7	11	10	5
5	4	12	9
12	10	3	8
6	12	8	8
9	8	4	12
3	8	5	3
9	6	8	11
12	9	12	6
11	12	7	3
4	3	5	10
7	9	3	9
12	5	8	3
3	3	6	8
10	12	11	4
7	6	7	6
10	11	10	6
6	7	6	11
5	5	11	7
8	3	6	9
4	10	7	11
11	9	12	5
10	4	4	7
3	7	10	4
11	7	4	12
8	4	11	4
5	10	9	10

ORDEN 6	ORDEN 7	ORDEN 8	ORDEN 9	ORDEN 10
8	9	7	6	6
10	3	11	7	5
9	10	4	10	11
11	5	10	3	8
3	10	12	11	5
6	5	7	6	9
12	7	3	3	4
7	12	12	12	11
9	6	6	10	12
4	9	3	8	3
11	12	8	9	10
10	4	4	5	8
3	11	11	4	12
12	7	6	10	7
9	11	12	9	3
12	6	7	6	4
7	8	11	11	10
3	4	8	4	9
4	9	10	6	5
10	7	8	8	7
3	5	5	9	3
8	6	3	11	6
11	9	10	8	11
6	8	9	7	6
3	3	5	5	10
3	11	9	12	4
6	4	7	7	12
6	3	5	3	8
3	12	9	12	7
5	10	4	4	6